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The methodology of a part lifetime calculation

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Abstract. Reducing mills in piece-reduction at the moment of capturing the pipe's front end and on the rear end exit are exposed to increased dynamic loads. However these processes at present time are not fully researched. The relevant problem is to decrease dynamic loads in the clamp engine, to increase reliability and durability of the clamp on the basis of the mill's production growth on the account of pauses decrease, rise of the production amount, and reducing in pipe costs. In the article the results of the study to define a part lifetime in the reducing mill stand have been presented. A part lifetime was calculated in month for more convenient comparison with the production data. The results have been hand over to JSC "PNTZ" for implantation.

In the study the researched 24th stand reducing mill is in the pipe rolling plant with a continuous mill (PRP 30-102) that is located on the JSC "Pervouralsk New Pipe Plant". The reducing mill has 3-roll stands with three inputs and also the group differential drive figure 1.

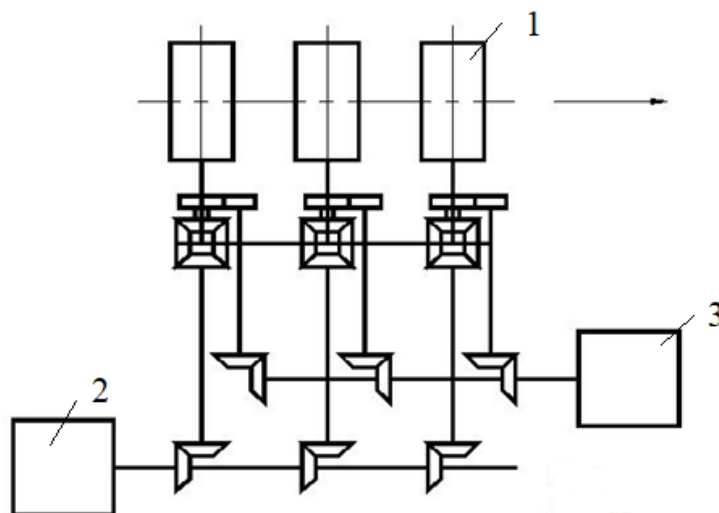


Figure 1. The kinematic scheme of the group differential drive: 1 – the stand; 2 – the main group engine; 3 – accessory group engine.

The kinematic scheme of the stand's drive is shown in figure 2.

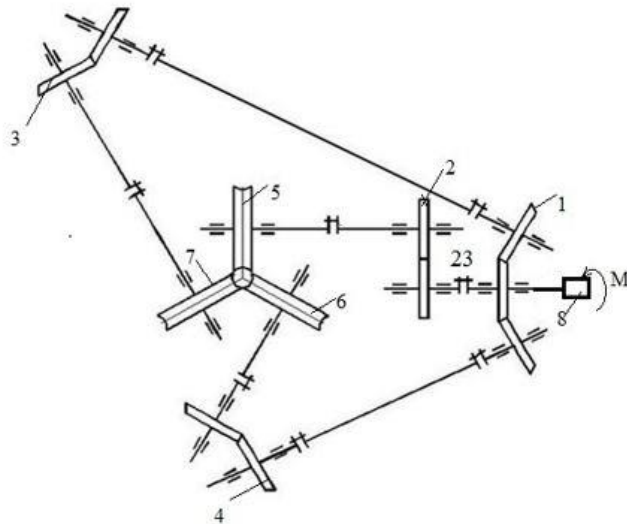


Figure 2. The kinematic scheme of the reducing mill drive: 1 – the triple conical reduction gear; 2 – cylindrical gear; 3, 4 – the double conical reduction gear; 5, 6, 7 – the roll; 8 – the electromotor; M – the torque.

The presented methodology of calculation allows to define a part lifetime. The methodology is shown on the example of the shaft's coupling, which is located on the zone 23 between the triple conical and cylindrical reduction gears (figure 2), because this zone is considered to be the most dangerous according to the solution of the differential equation system [1-6]. The calculation is carried out for current values of the system parameters by the known methodology in months to more convenient comparison with the production data.

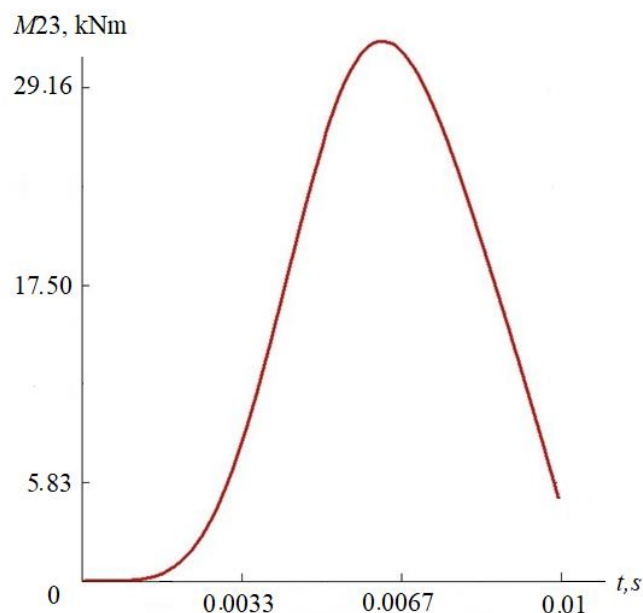


Figure 3. The “elastic strength moment M_{23} – the peak load time t ” diagram on the 23 area: $M_{23} = 32.827$ kNm.

Let's define the number of loading cycles in month

$$N_c = \frac{2 \cdot 3600}{T_r} \cdot K_h \cdot K_d,$$

where K_h – the coefficient of hourly usage (the amount of hours in a day); K_d – the coefficient of daily usage (the amount of days in a month); T_r – the rolling productivity.

With $K_h=24$; $K_d = 22$; $T_r = 16$ have $N_c = 2.367 \cdot 10^5$.

Then calculate the peak value of stress

$$\tau_v = \frac{M_{23}}{2 \cdot W_p},$$

where M_{23} – the maximize moment of the elastic strength in the area 23, Nm; W_p – the moment of the cross-section resistance to torsion, m³; τ_v – the peak value of stress, N/m².

Since $M_{23} = 32827$ Nm see figure 3 and $W_p = 0.0001$ according to [1, 8-10], then $\tau_v = 164.135 \cdot 10^6$.

Let's define the effective value of stress

$$\tau_{ef} = \frac{K_\tau \cdot \tau_v}{E_s \cdot E_r} + \Psi_\tau \cdot \tau_m,$$

where K_τ – the shear effective coefficient of stress concentration; E_s – the shear stress scale factor; E_r – the coefficient of the surface roughness influence; Ψ_τ – the coefficient of a material sensitivity to the cycle asymmetry; τ_m – the mean stress, N/m²; τ_{ef} – the effective value of stress.

Substituting $K_\tau = 1.3$; $E_s = 0.8$; $E_r = 0.9$; $\tau_v = \tau_m$ [6]; $\Psi_\tau = 0.05$ [7], obtain $\tau_{ef} = 304.562 \cdot 10^6$ N/m².

Let's write down the equation of the Veler's curve

$$N = Nb \cdot \left(\frac{\tau_1}{\tau_{ef}} \right)^m$$

where Nb – the basic number of the loading cycles; τ_1 – the shear yield strength, N/m²; m – the index of the Veler's curve; N – the number of cycles before failure see figure 4.

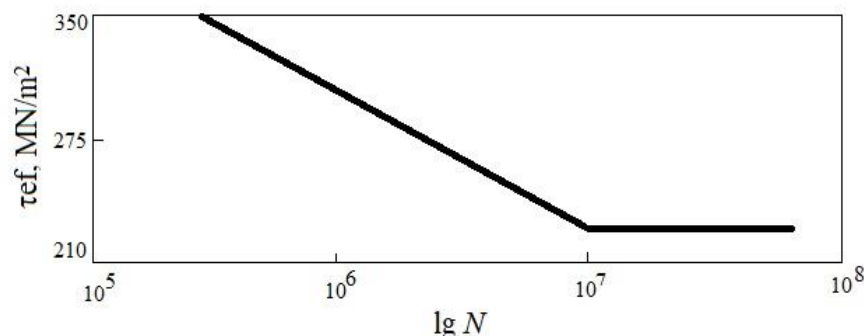


Figure 4. The Veler's curve.

Considering $\tau_1 = 240 \cdot 10^6$ [6]; $N_b = 10^7$; $m = 9$ [7], the number of cycles is $N = 1.172 \cdot 10^6$. Then the lifetime of the shaft coupling is

$$S = \frac{N}{N_c},$$

where S – the lifetime of a part, $S = 4.9$.

Thus, the lifetime of the shaft coupling is within 5 month.

The results of the shaft coupling lifetime evaluation obtained by current values of the system parameters have been approved by the data of the actual failures of the parts of reduction mill of the pipe-rolling plant 30-102 JSC “PNTZ” [1], which allows to make a conclusion about adequacy of the presented mathematical models.

The results of the work and the developed methodology could be applied for the endurance evaluation of the other types of reducing mill parts with the similar kind of loading and kinematic scheme.

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